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AN ANALYSIS OF LETTERING STYLES FOR AN IMPROVED RASTER-TYPE DAT--ETC(U)
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An Analysis of Lettering Styles for an Improved Raster-Type Data Display

by

Leonard C. Moore
Paul M. Nida

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FEDERAL AVIATION AGENCY
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

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AN ANALYSIS OF LETTERING STYLES FOR AN IMPROVED RASTER-TYPE DATA DISPLAY

SUMMARY

This report contains an analysis of a study and evaluation conducted for the purpose of developing an improved data presentation to be used with raster-type pictorial air traffic control displays. A satisfactory data presentation is a highly desirable function of radar target-tracking markers. It was necessary to design a new style of alpha-numeric characters to satisfy the present requirements for a SPANRAD data display; thus, the development of alpha-numeric symbols suitable for use with SPANRAD is described in considerable detail. This new design incorporates available information on legibility and the specific requirements of the air traffic control environment, making possible the following set of principles for immediate application:

1. Use "bold" characters; that is, a type style which is thick and heavy in appearance in both horizontal and vertical strokes.

2. Use "expanded" type; that is, a block or square style as opposed to a condensed style, which is tall and narrow in appearance.

3. Use maximum contrast between character and background, characters intense white and background dead black.

4. Use symbols which are nine to ten raster lines in height.

5. Use horizontal spacing which is 10 to 20 per cent of the vertical height of the characters.

6. Use a vertical spacing of three raster lines between lines or rows of characters.

7. Use only upper case letters.

8. Provide a very brightly illuminated target for the TV camera.

If continued use of raster-type displays is desired, it is recommended that (1) the new design be adopted for SPANRAD data displays, and (2) a detailed technical study be made of SPANRAD marker illumination requirements.

INTRODUCTION

Small data display markers, bearing aircraft identification, altitude, and so forth, in the form of alpha-numeric characters, are used to identify and follow radar targets on the superimposed panoramic radar

display (SPANRAD). The markers are viewed by a TV camera and displayed on a studio-type monitor. While these markers, sometimes called "shrimp boats," were used with some measure of satisfaction as SPANRAD target markers, they did not provide a suitable display of flight data.

The TV camera of SPANRAD provides for the display of the markers on a TV screen and the scan-converter equipment permits the display of radar targets on the same screen. Thus, the desirability of the simultaneous display, on that same screen, of the pertinent flight data associated with each marker is apparent. Such a display would eliminate the necessity for a controller to divide his attention between radar, the primary display, and flight-data strips, the secondary display.

The use of data markers in the control of air traffic is not new; however, with the advent of SPANRAD, new problems arose. The inherent characteristics of TV equipment, that is, number of lines in the raster, camera resolution, lighting, and the like, together with the lack of comprehensive technical information pertaining to alpha-numeric symbols as applied to TV, complicated the development of an operationally satisfactory display of control data via this medium. The firm of Courtney and Company, under contract to the Technical Development Center, conducted some research and experimentation dealing with this problem.[1, 2]

An examination of some of the fundamental aspects of the data display problem indicated that the key to its solution lay in selecting or designing a satisfactory set of alpha-numeric symbols. An empirical evaluation indicated that the legibility of letters and numbers on a TV screen may be drastically different from their legibility on the printed page due to TV characteristics.

The procedures adopted for the evaluation were to some extent dictated by two fundamental criteria for a desirable SPANRAD data marker. These are (1) minimum-size, alpha-numeric characters which are omnilegible, or legible regardless of either character or observer position, and (2) a marker large enough to contain essential flight data, yet small enough to enable the controller to follow the maximum number of targets.

A preliminary study indicated that these criteria precluded the use of available type fonts for SPANRAD operation. The first criterion, minimum-size, omnilegible symbols, was treated as the focal point for examination and was separated into the following components: (1) type style, (2) type size, (3) spacing, (4) contrast, and (5) illumination. A study of the problem posed by the second criterion will be the subject of a later report.

[1] Memorandum #1, May 15, 1958 (unpublished).

[2] Report #21, Project M, July 1, 1958 (unpublished).

EQUIPMENT AND TEST ENVIRONMENT

The tests were conducted at the Technical Development Center (TDC), at Indianapolis, Indiana. Equipment consisted of a closed-circuit, 625-line TV system, photographs and samples of various type fonts, colored metal plates, and a SPANRAD unit. The closed-circuit TV component of SPANRAD was the equipment used for the evaluation. The SPANRAD system was operated and used to verify the results obtained.

The SPANRAD camera used in this evaluation viewed a 30- by 36-inch plotting area which had been painted a flat black. The objects viewed on this plotting area were displayed on a 27-inch TV tube. The tube face had a height of 18 1/2 inches and a width of 24 inches. Thus, an approximate 3:2 ratio existed between the size of the plotting area and the size of the TV tube.

The TV camera, an RCA Type TK 21B, was mounted horizontally in a fixed boom perpendicular to the TV screen and projecting over the center of the tracking board. It was equipped with an f 1:4, 25-mm lens, with an f 2 setting. The lens face was approximately 5 inches from a 6- by 8-inch, front-silvered mirror mounted at a 45° angle. The distance from the mirror to the tracking board was approximately 63 1/2 inches. The ambient light was approximately 20 foot-candles, furnished by 320 watts of fluorescent lighting. The lighting consisted of two groups of 48-inch, cool white fluorescent tubes, each tube rated at 40 watts, mounted on opposite sides of the face of the TV screen. Each group was centered 50 inches from, and perpendicular to, the camera boom. The distance from the center of each light fixture to the center of the tracking board was approximately 9 feet. See Fig. 1.

TEST PROCEDURES

The evaluating group first screened the relatively few studies available which were pertinent to the problem. As a result of the screening, many type styles were eliminated from further consideration, since they obviously were unacceptable. Of the remaining type styles, those which appeared to be nearest to meeting the basic requirements for acceptability were selected for further study.

Samples of those type styles chosen then were obtained and photographic reproductions were made of each style. Character height was varied from 3/16-inch to 3/4-inch, in increments of 1/16-inch. Each style was reproduced, in each size, in both white on black and black on white. These samples then were prepared for observation of form of individual characters in each style and of each size in a particular style. In addition, random groups of characters and random groups of words were prepared for the purpose of observing multicharacter cohesion.

The evaluation incorporated the TV portion of the SPANRAD equipment and the target tracking board. There were several phases in the evaluation. These were:

Phase 1 - Selection of the Minimum-Size Legible Character.

Random characters in each size of each style were placed on the tracking board, and through the process of direct observation of the characters as displayed on the TV screen, the minimum legible size was quickly ascertained.

Phase 2 - Selection of the Most Acceptable Style.

Starting with the letter A and proceeding in sequence, each style of each letter of the alphabet was evaluated on a "yes - no" basis. If "yes," the style of the letter was set aside for further comparison. If "no," the style of the letter was not considered for further comparison. Each style required a majority vote of the evaluating group in order to qualify for further comparison. When this primary selection was completed, all of the styles of each letter were evaluated again in alphabetical sequence to select the best style of those available. This same procedure was followed in evaluating the numerals. In some instances there was no acceptable style for either a particular letter or numeral.

When the style selection was completed, each letter then was subjected to a detailed study. Each letter first was placed on the SPANRAD tracking board in a normal horizontal position, then rotated through 360° so that the character could be observed in and from all angles. During this process, comments from the observers were recorded; for example, "B appears as an 8 at 90°."

The recorded comments and criticisms became the basis for desirable features to be incorporated in the design of a new alphabet style. Several designs of each letter were drawn as shown in Fig. 2A, 2B, and 2C, and then subjected to the evaluation process described above. The best of the new designs then was compared with the best of the previous styles for a final style selection.

Phase 3 - Selection of the Most Acceptable Form of Contrast.

This selection was considered from two viewpoints: (1) data displayed simultaneously on the tracking board and on the TV screen, and (2) data displayed on the tracking board but not displayed on the TV screen, in order to reduce screen clutter.

Under Item (1), comparison was made between white on black and black on white. These colors were selected since they afforded the maximum available contrast. The samples were placed on the tracking board for direct observation of the data on display. Then, by observation of the same data displayed on the TV screen, the evaluating group was able to determine which contrast form presented the most satisfactory legibility.

Under Item (2), the color combinations of red on black and black on red were selected. This choice was based upon the fact that these colors present a minimum of contrast in normal TV presentation, but retain their true color values on the tracking board. In order to determine whether dark red was better than light red, metal plates painted either dark or

light red were placed on the tracking board. When the choice of red was made, the evaluation group wrote letters in random order, with black grease pencil, on the red plates. By this method, a direct comparison and evaluation were possible.

Phase 4 - The Effect of Illumination Upon Marker Legibility.

A very limited investigation was conducted on the SPANRAD display. Three levels of illumination were tried with white on black and black on white target markers. Although the brightness levels were not measured, they were clearly and distinctly different.

Phase 5 - Requirements for the Vertical and Horizontal Spacing of Characters.

a. Random pairs of characters were placed in a single, horizontal row with a variable spacing between characters. The amount of spacing varied from zero, where the characters touched, to 100 per cent of the character height.
b. Appropriate characters were selected to simulate the partial display of flight data. These characters were treated with the same spacing variations as stated in a., above.
c. Random characters were placed in a vertical row with spacing between characters variable from zero to 100 per cent of the character height.
d. Three horizontal rows of characters representing flight data were so arranged that the vertical spacing between rows varied from zero to 100 per cent of the character height.

RESULTS

A review of available literature indicated that an acceptable style of type face would be typified by a generally square outline and thick, sharply defined vertical and horizontal lines. Precautions against ultrasimplification of type must be taken, since the loss of even one component in transmission of a character may lead to an error. For example, should the terminal slash of an R be blurred, the letter may be read as P in some styles. Opposed to the ultrasimple style is the overidentified style which tends to be transmitted as a single blur. Examples of unsatisfactory type styles are presented in Fig. 3.

It was found that character identification may be accomplished by a combination of two methods; first, by the use of serifs for distinguishing letters of similar appearance, and second, by the use of character form to carry the burden of discrimination. Since individual type fonts generally utilize one single style (for example, serifs), examination revealed that a combination of fonts must be considered in order to select an acceptable style for a SPANRAD alphabet.

The theoretical minimum height for legibility on closed-circuit TV systems is five raster lines per character; however, the operational

minimum is seven lines, provided that the entire system is operating properly. A more practicable standard is nine to ten lines per character, provided that the type style is suitable. If size were no object, then characters of 12 lines or more in height would be even more suitable for the human viewer. The width of the characters should be approximately 75 per cent of the height and the line or stroke thickness should be between 20 and 25 per cent of the height.

Type Style.

The data suggested that letters of the Memphis Bold, Memphis Extra Bold, Spartan Bold, or Square Gothic type styles would be the most legible of those available. This was verified during the evaluation. It was observed, however, that when the individual characters were placed in positions other than for normal reading, many of the characters either filled in or blurred. The letter C, for example, became an O, while the figure 8 and the letter B appeared the same. While some italicized numerical characters were quite good, italicized alphabetical characters were completely unsatisfactory when not in a normal position. The final selections of the commercially available styles which appeared to be the best were letters, Memphis Bold, and numerals, Spartan Bold Italic. See Fig. 4.

The factors stated above created a situation wherein it became mandatory that a new style alphabet be designed in order to meet the operational requirements. A satisfactory style has been developed. See Fig. 5. A photograph of this style as viewed on a TV screen, using normal ambient light, is shown in Fig. 6.

Type Size.

In order to achieve a 9- to 10-line height, the alpha-numeric characters required a vertical height of 3/8-inch due to the 625-line TV system. When using a 3:2 ratio between the plotting board and the TV tube, this 3/8-inch height, when viewed on the TV tube, was reduced to approximately 1/4-inch.

A measurement of letters on a standard eye test chart showed that under nearly perfect conditions, a person viewing a 3/8-inch-high letter should be able to read the letter at a distance of 15 feet. A letter 3/16-inch high should be readable at a distance of 10 feet. When considering this scale, a SPANRAD operator should be able to read a letter 1/8-inch high at the normal operating distance of 4 feet provided that both the viewing conditions are nearly perfect and that an adequate raster system is used. This requires that a 3/16-inch-high character be viewed by the TV camera, due to the 3:2 reduction ratio.

Spacing.

The minimum vertical spacing between either individual characters or rows of characters varies from 3 to 4 raster lines, or approximately 1/8-inch when using the 625-line raster system. It was noted that rows of characters formed a figure or pattern which had considerable cohesion, and therefore, the rows could be placed fairly close together.

The minimum horizontal spacing varies from 10 to 20 per cent of the character height. This minimum depends, at least in part, on the characters involved. For example, in some styles, if the numeral 1 is followed too closely by a 3, the result appears as a B, but if 1 is followed closely by an X, both letters transmit satisfactorily. A review of previous studies indicated that a horizontal spacing of 50 per cent of character height is the maximum for satisfactory results under any operating conditions.

Contrast.

Two conditions of contrast must be considered: (1) information to be used on the plotting board and to be displayed on a TV screen, and (2) information to be used on the plotting board but not displayed on a TV screen.

1. There is a considerable amount of published information concerning the use of white on black versus black on white for visual perception. Some of the material is contradictory. In either case, a high contrast is a requisite to good legibility. In the case of TV, it is obvious immediately to the observer that white on black is superior to black on white. Four experienced SPANRAD operators estimated the superiority at 50 to 75 per cent. A very crude psychophysical check revealed that observers were able to read correctly a white-on-black type which was approximately one-third smaller than the identical type in black on white.

2. Occasionally there is an operational need to follow a radar target but not show the target marker on the TV screen in order to reduce screen clutter. A peculiarity of black and white TV is that different intensities of red photograph as corresponding intensities of gray. In view of this, and since the plotting board is black, marker color combinations of black on red and red on black were evaluated for direct visual perception. It was estimated that black letters on a light red background were 20 per cent more legible than black letters on a dark red background. Black on light red was estimated to be 30 to 40 per cent superior to either shade of red on a black background.

Illumination.

There appears to be a definite correlation between contrast, size, visual acuity, and background brightness. A very limited investigation of SPANRAD target-marker illumination was performed. The three levels of illumination were:

1. 320 watts of cool white fluorescent lighting, from a distance of 8 to 10 feet.

2. Two 150-watt incandescent lamps in reflectors, from a distance of 4 feet.

3. Two No. 2 photoflood lamps, from a distance of 4 feet.

Illumination system No. 3 was so bright as to dazzle the observers and overload the TV circuitry. In addition, the amount of heat emitted from the lamps was unbearable to the observers, so it had to be abandoned. Illumination system No. 2 was brighter and clearly superior to system No. 1 in that the same markers were more visible, smaller type could be read with equal success, and type styles which were previously illegible were considerably improved or became completely legible.

CONCLUSIONS

1. The study and evaluation of commercially available type styles indicate that none are satisfactory for use with SPANRAD.

2. The alpha-numeric characters developed during this study are satisfactory for marker data display and it is believed they are satisfactory for use with any raster-type display.

3. The evaluation demonstrated that SPANRAD, using a 625-line raster system, requires properly spaced upper case characters of 3/8-inch minimum height provided that a satisfactory type style is used. It appears that a TV system, using a 27-inch display tube and containing 875 lines in the raster, would permit a reduction in alpha-numeric character size of approximately one-third.

4. It appeared that for optimum alpha-numeric character legibility on closed-circuit TV systems, the characters should be light and should be displayed on a dark background. However, in another situation where less contrast was desired (as for reduction of screen clutter), black characters on a light red background produced the best results.

5. In general, it may be stated that, within limits, the brighter the illumination the greater the character legibility.

RECOMMENDATIONS

It is recommended that:

1. An investigation be made to ascertain a suitable method of reproducing the character style developed during this study, and that a method be developed for rapidly forming and changing the desired arrangement of alpha-numeric flight information, so that the target marker may indicate current flight data.

2. The alpha-numeric character style developed during this study be used for the SPANRAD marker data display, using either the 625- or 875-line raster system, or for any other raster-type data display.

3. SPANRAD marker illumination be given an exhaustive technical study.

4. A technical study be made of color combinations, as applied to raster-type displays, to resolve the apparently conflicting results derived from the tests during this evaluation.

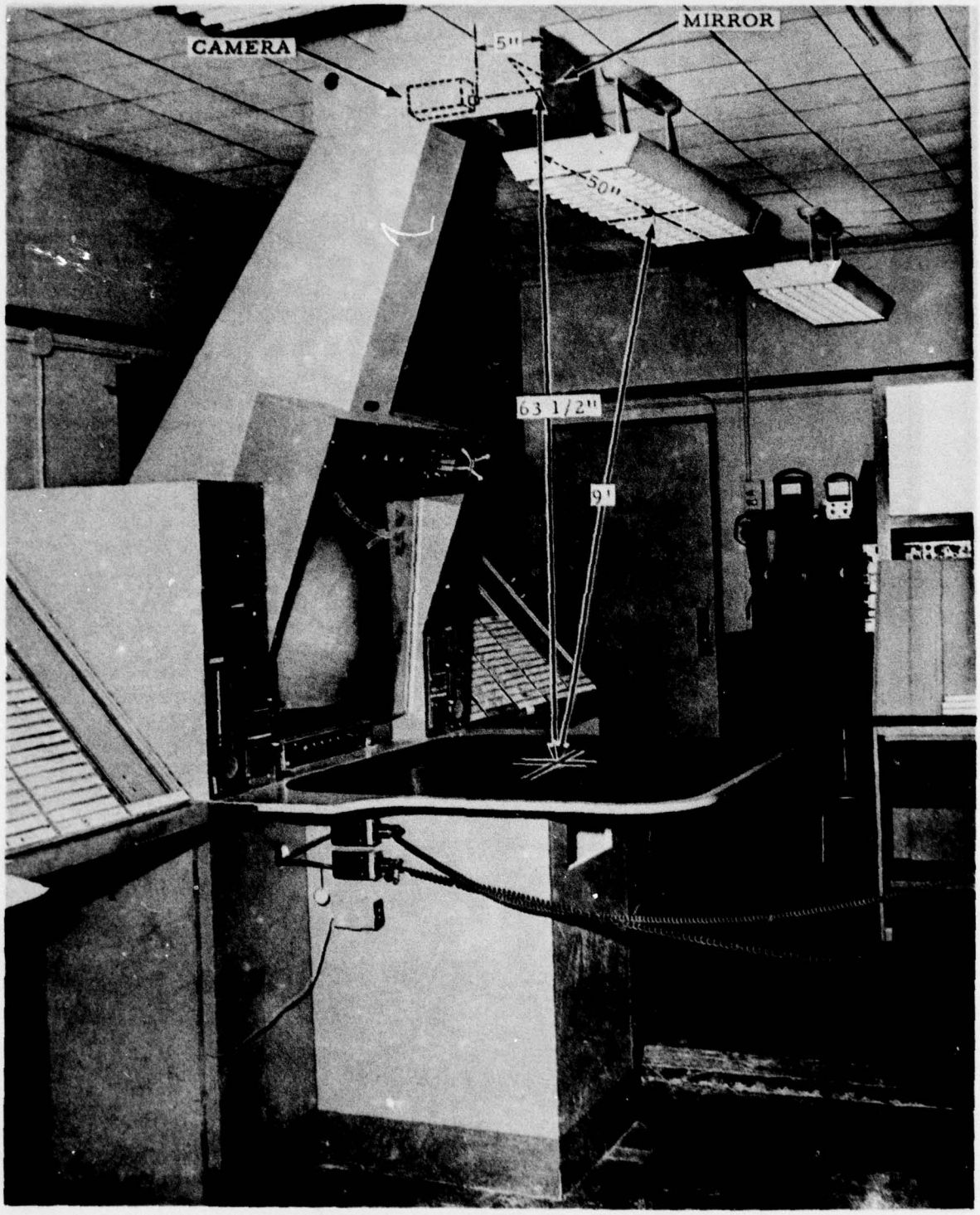

FIG. 1 TEST ENVIRONMENT

FIG. 2A EXPERIMENTAL DESIGNS

FIG. 2B EXPERIMENTAL DESIGNS

FIG. 2C EXPERIMENTAL DESIGNS

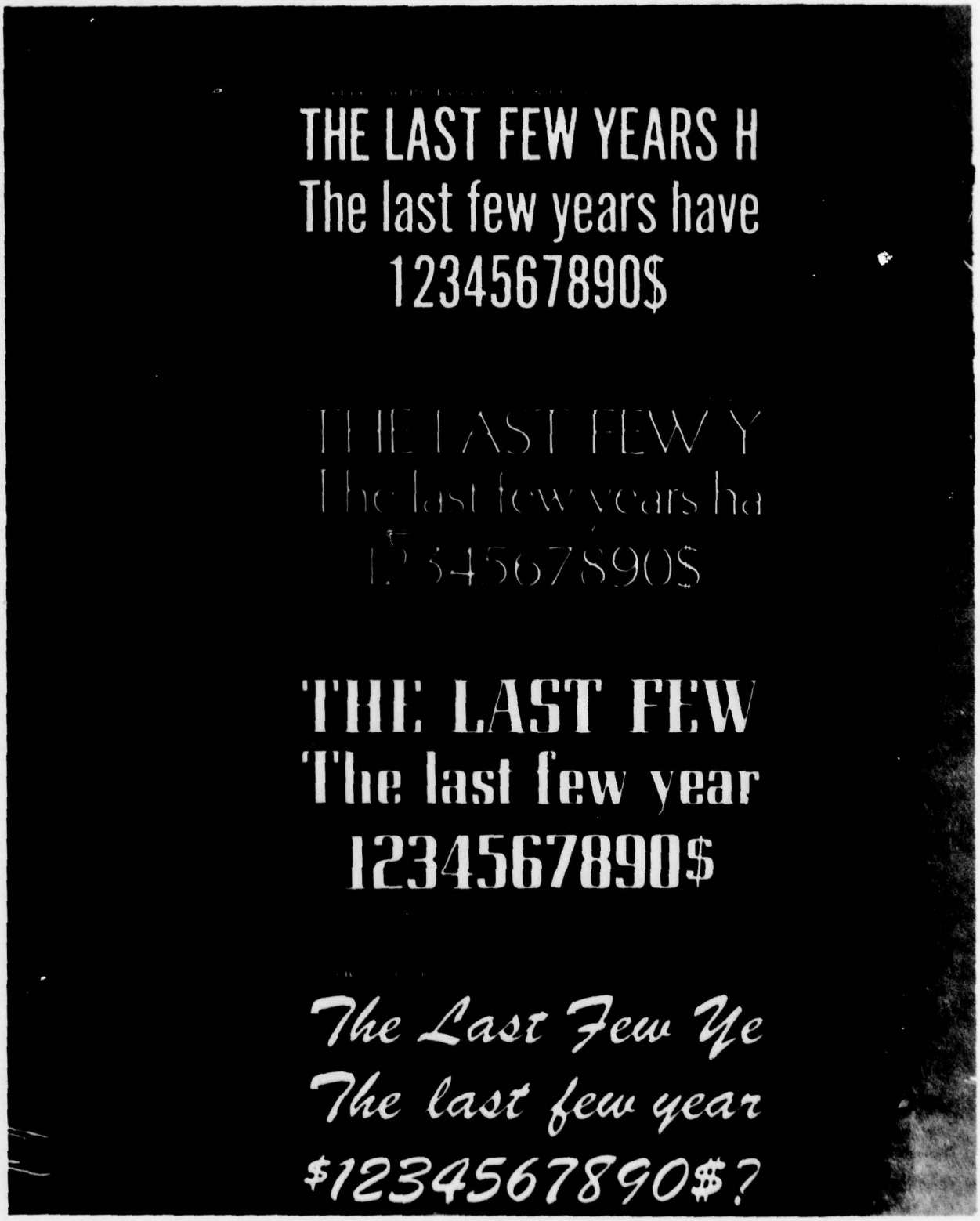

FIG. 3 EXAMPLES OF UNSATISFACTORY LETTER STYLES

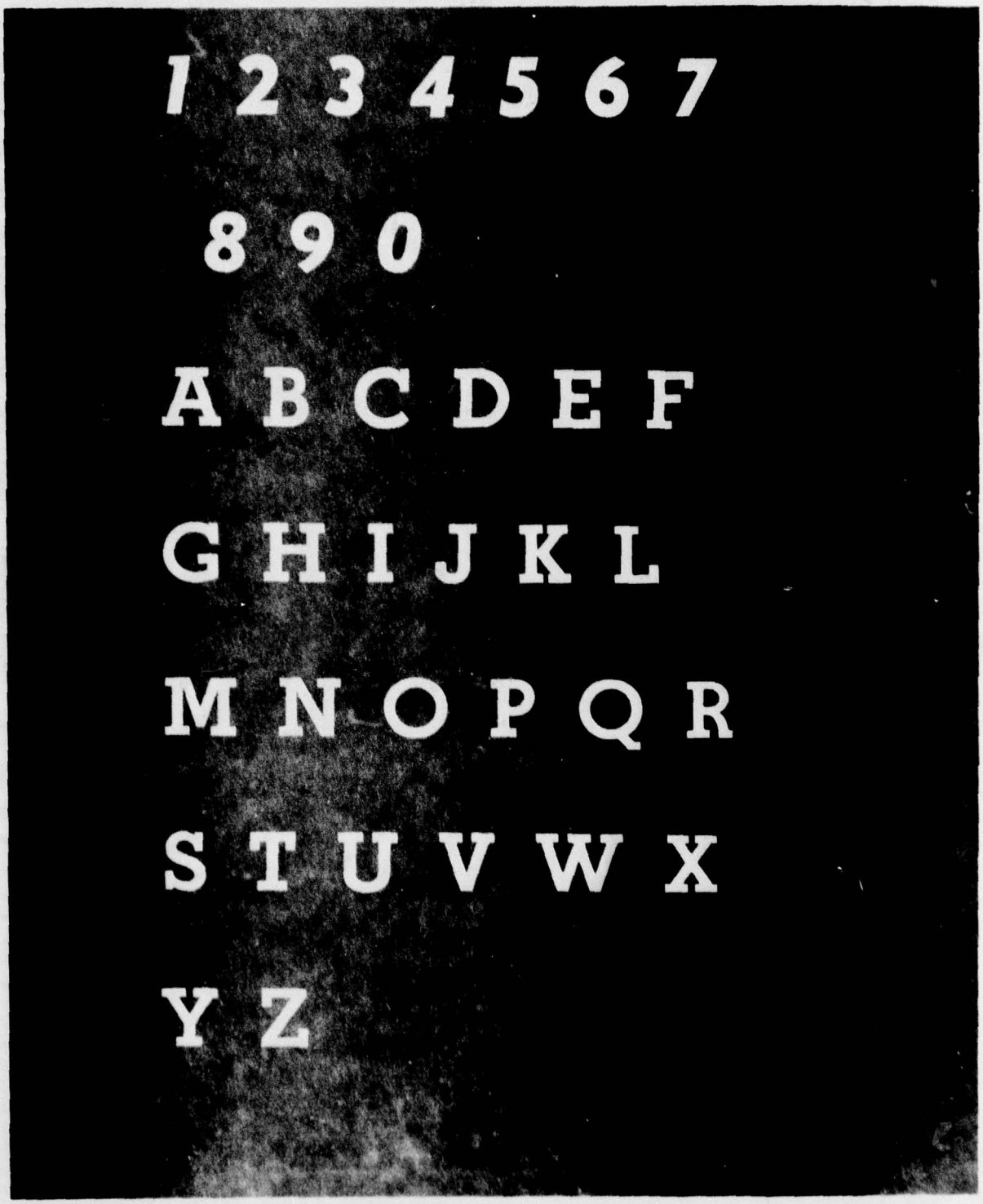

FIG. 4 BEST COMMERCIAL STYLE

FIG. 5 SATISFACTORY STYLE FOR RASTER-TYPE DISPLAYS

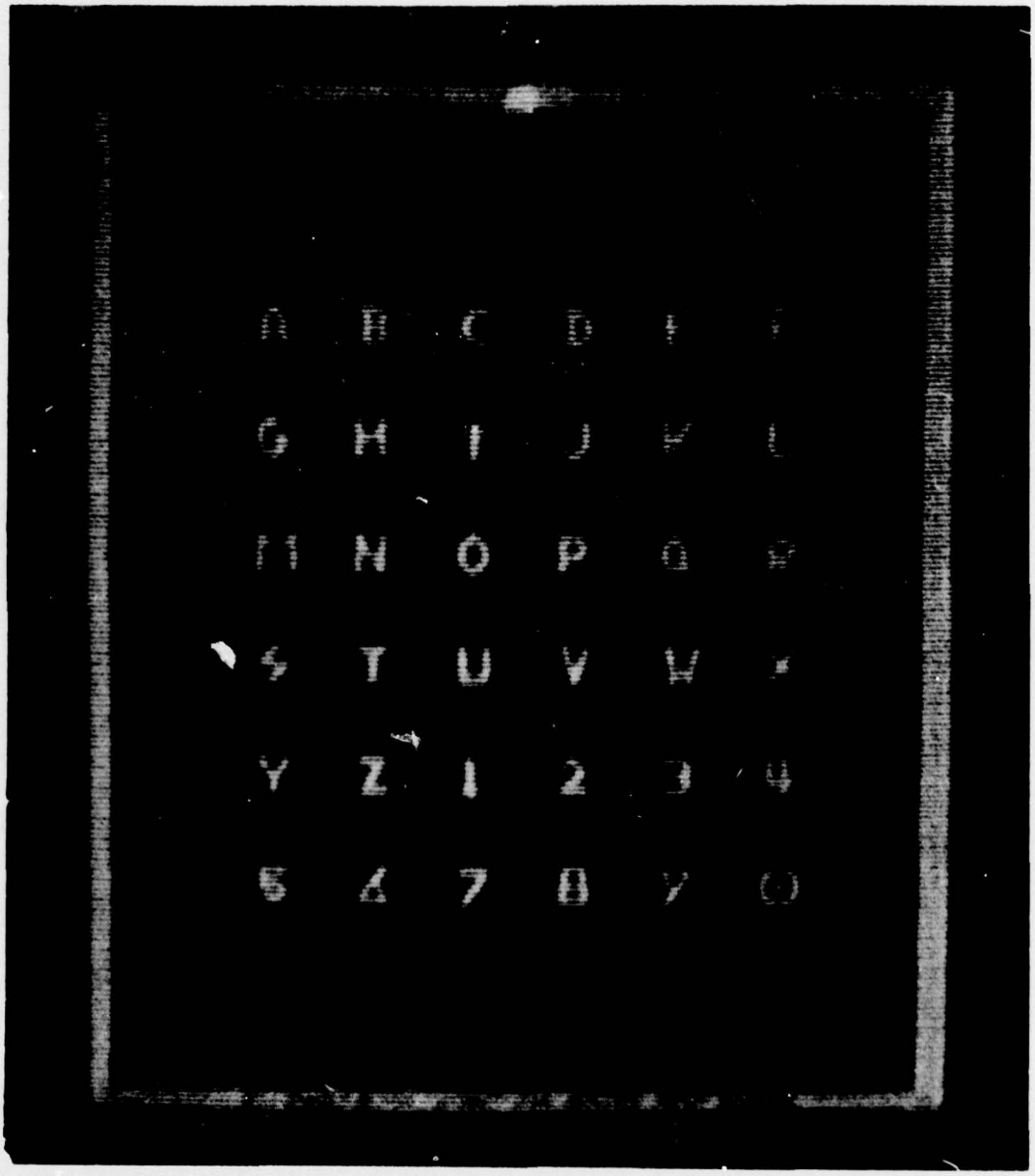

FIG. 6 PHOTOGRAPH OF SPANRAD TUBE FACE PRESENTING NEW DESIGN